The Evolution of Payload Data Capabilities on the Commercial Visiting Vehicles that Service the International Space Station

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Executive Summary

- The visiting vehicles designed by U.S.-based commercial companies to deliver cargo and crew to the International Space Station (ISS) can transfer science payloads to the ISS in an active, powered state.

- To provide payload developers with situational awareness during transit, NASA is working with current and future visiting vehicles to offer a variety of payload monitoring and control capabilities.

- **This presentation will offer discussion of the following topics:**

  - How NASA requirements for the data services available to ISS payloads on the visiting vehicles have expanded over time.

  - The challenges that have been faced in establishing these services.

Agenda

① **Overview of ISS Commercial Vehicle Contracts**

② **Introduction to the MSFC POIC**

③ **Overview of Visiting Vehicle Data Services for ISS Payloads**

- *Timeline Phasing for Payload Data Services*
- *Pressurized Payload Data Services*
- *Unpressurized Payload Data Services*
- *Sortie Payload Operations Support*

④ **Technical and Programmatic Challenges Faced While Establishing These Payload Services**

① Overview of ISS Commercial Vehicle Contracts

ISS Visiting Vehicle Development and Mission Execution Contracts

- **2008: Commercial Resupply Services 1 (CRS1)** contracts awarded to Space Exploration Technologies (SpaceX) and Orbital Sciences.
- **2013: Commercial Crew Transportation Capability (CCtCap)** contracts awarded to SpaceX and Boeing.
- **2016: Commercial Resupply Services 2 (CRS2**) contracts awarded to SpaceX, Orbital ATK (formerly Orbital Sciences) and Sierra Nevada Corporation (SNC).
- NASA requirements for science payload data services have expanded with each set of contracts.

② Introduction to the MSFC POIC

POIC Overview

- To enable payload developers to have insight into how their experiments are operating during the transit phase, the POIC has established interfaces to the commercial vehicle control centers.

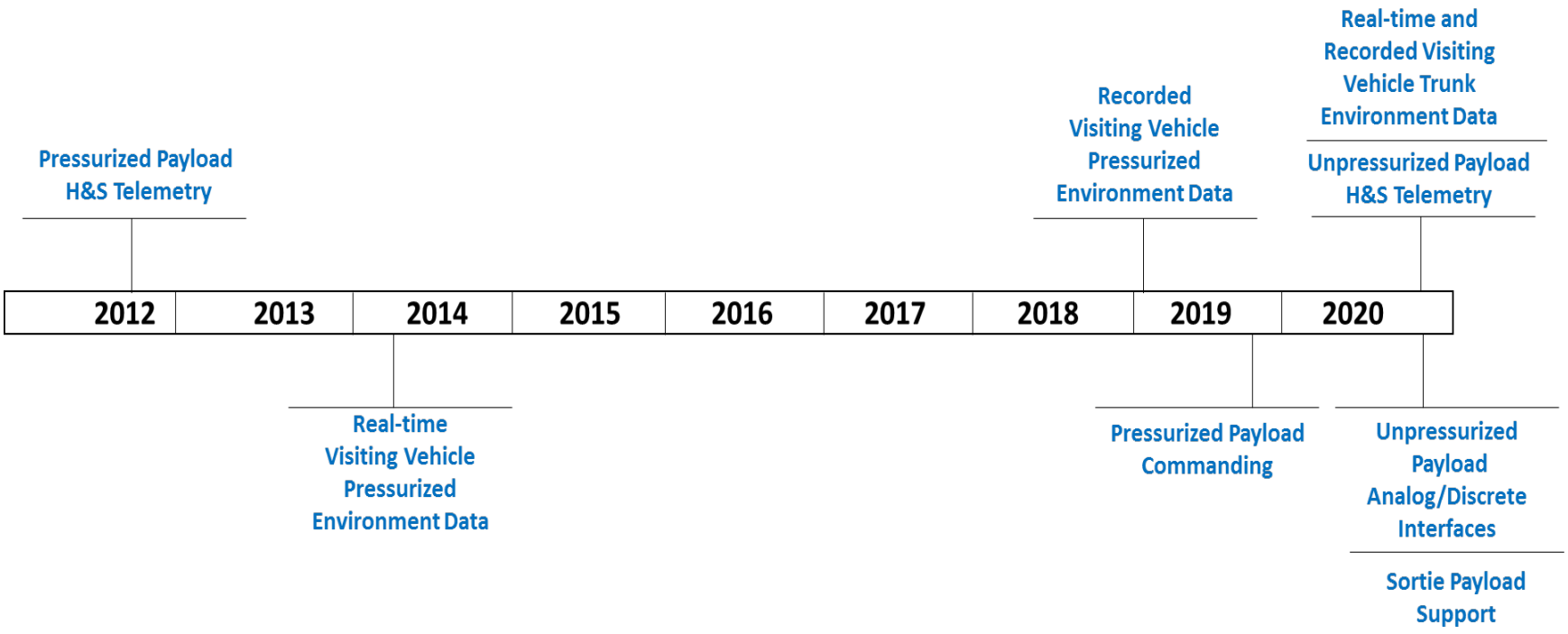
- **Location:** NASA Marshall Space Flight Center, Huntsville, AL.

- The POIC is an ISS facility that manages the execution of on-orbit ISS payloads and payload support systems.

- **Services provided to support science operations include:**
  - Telemetry
  - Commanding
  - Mission Planning
  - Data Storage / Retrieval Services
  - Voice
  - Video

③ Overview of Visiting Vehicle Data Services for ISS Payloads

Timeline Phasing for Payload Data Services



Pressurized Payload H&S Telemetry

2012 / CRS1

- This capability provides payload developers whose experiments are designed to be integrated into ISS **EX**pedite the **PR**ocessing of **E**xperiments to **S**pace **S**tation (EXPRESS) racks to receive payload-generated health and status (H&S) data.

- ***Purpose:*** Situational awareness to enable quick detection and diagnosis of payload anomalies.

- ***Goal:*** EXPRESS payloads designed for the ISS can get H&S telemetry while on a commercial visiting vehicle without having to implement payload hardware or software changes.

Pressurized Payload H&S Telemetry - 2

- **Interface description:**
  - Ethernet data connections
  - Transmission Control Protocol / Internet Protocol (TCP/IP) software protocol
  - Common payload IP addressing on the ISS and on the visiting vehicles
  - The visiting vehicle control center extracts payload H&S telemetry from the spacecraft downlink and sends the packets to the POIC.
- **EXPRESS Payload H&S Telemetry is available:**
  - Whenever a payload is integrated into a visiting vehicle and powered (at least once per 5 – 10 minutes).
  - Through the POIC in real-time and post-mission from the POIC storage system.

Real-time Visiting Vehicle Pressurized Environment Telemetry

2014 / CRS1

- This capability enables payload developers to retrieve a subset of commercial vehicle telemetry that characterizes the payloads' operational environment within the pressurized cabin.

All Missions with Powered Cargo:	
• Vehicle Cabin Temperature	• Payload Power Draw (Current and Voltage)
• Vehicle Cabin Pressure	• Vehicle Cabin Relative Humidity
Additional Parameters Available for Missions with Active Environment Modules (AEMs):	
• Vehicle Cabin Carbon Dioxide (CO_2) Content	• Vehicle Cabin Oxygen Content (O_2)

- ***Purpose:*** situational awareness, context for anomaly investigation, and for use in ground control experiments.

- ***Goal:*** Implement this service using a telemetry format that can be standardized across partners.

Real-time Visiting Vehicle Pressurized Environment Telemetry - 2

- ***Interface description:***
  - Vehicle telemetry is downlinked to the commercial vehicle's control center.
  - The vehicle's control center then extracts the telemetry of interest to payload developers, packages the data points into a NASA standard format, and then sends the telemetry to the POIC.

- ***Pressurized Environment Telemetry is available:***
  - Whenever a payload is integrated into the visiting vehicle.
  - Every 10 seconds.
  - Through the POIC in real-time and post-mission from the POIC storage system.

Recorded Visiting Vehicle Pressurized Environment Telemetry

2019 / CCtCap

- Payload developers can receive real-time vehicle pressurized environment data today. In the future, payload developers will also be able to receive environment data from time periods in which the commercial vehicle had a loss of signal (LOS) during missions.

- ***Purpose:*** Comprehensive mission profile of environmental conditions for anomaly investigation and for use in ground control experiments.

- ***Interface description:*** The commercial vehicle will record environment data during LOS periods and provide the data to the POIC within 24 hours of mating with the ISS / landing back on Earth.

Pressurized Payload Commanding

2019 / CRS2

- This capability will provide payload developers with the ability to transfer files and access command line services to initiate payload configuration changes and to turn equipment on/off during free-flight time periods.

- ***Purpose:*** Ensure payloads arrive to the ISS ready to execute their science missions.

- ***Goal:*** Implement a payload command service that will support payloads currently on the ISS and be flexible enough to support a wide range of use-cases to account for potential needs of future, not yet defined payload customers.

Pressurized Payload Commanding - 2

- ***Interface description:***
  - The commercial vehicle will support payload developer access to payload Local Area Network (LAN) devices on the visiting vehicle using the following IP services:

Protocol	Visiting Vehicle IP Service
Internet Control Message Protocol (**ICMP**)	**Ping**
Transmission Control Protocol (**TCP**)	Hypertext Transfer Protocol Secure (**HTTPS**)
	Secure Shell (**SSH**)
User Datagram Protocol (**UDP**)	CCSDS File Delivery Protocol (**CFDP**)

Technical Parameter:	Minimum Threshold:
Bi-directional Bandwidth	56 Kbps (total, shared across all payloads)
Latency	One second (round-trip)
Maximum Transmission Unit	1500 bytes
Availability during Ascent/Descent	Five minutes minimum duration per command window

  - Payload developers will be able to access these services using POIC software tools.

Unpressurized Payload H&S Telemetry

2020 / CRS2

- This capability provides payload developers whose experiments are designed to be integrated into ISS **EXPRESS Logistics Carriers** (ELC) to receive payload-generated health and status (H&S) data.

- ***Purpose:*** Situational awareness, enable quick detection and diagnosis of payload anomalies

- ***Goal:*** ELC payloads designed for the ISS can get H&S telemetry while on a commercial visiting vehicle without having to implement payload hardware or software changes.

Unpressurized Payload H&S Telemetry - 2

- **Interface description:**
  - MIL-STD-1553 or Ethernet data connections
  - The visiting vehicle control center will extract the subsets of ELC payload H&S telemetry from the spacecraft downlink and provide the packets to the POIC.

- **ELC Payload H&S Telemetry is available:**
  - Whenever a payload is integrated into a visiting vehicle and powered.
  - Once per day while the vehicle is on the pad, once per minute all other times.
  - Through the POIC in real-time and post-mission from the POIC storage system.

Real-time and Recorded Visiting Vehicle Trunk Environment Telemetry

2020 / CRS2

- This capability will enable payload developers to retrieve a subset of commercial vehicle telemetry that characterizes the payloads' operational environment within the trunk.

Additional Parameters Available for Missions with Active Unpressurized Payloads:	
• Temperatures of the Vehicle Structure Exposed to Cargo	• Cargo Heater Power Consumption (Voltage and Current)

- ***Purpose:*** Comprehensive mission profile of trunk environmental conditions for anomaly investigation.

- ***Goal:*** Implement this service using a telemetry format that can be standardized across partners.

Real-time and Recorded Visiting Vehicle Trunk Environment Telemetry - 2

- ***Interface description:***
  - Vehicle telemetry is downlinked to the commercial vehicle's control center.
  - The vehicle's control center then extracts the telemetry of interest to payload developers, packages the data points into a NASA standard format, and then sends the telemetry to the POIC.
- ***Unpressurized Environment Telemetry is available:***
  - Whenever a payload is integrated into the visiting vehicle.
  - Every 10 seconds on the pad prior to launch, once per second all other times.
  - Through the POIC in real-time and post-mission from the POIC storage system.

Analog and Discrete Interfaces for Unpressurized Payloads

2020 / CRS2

- These interfaces will enable unpressurized payloads to receive analog and discrete input signals from the commercial visiting vehicle.

- ***Purpose:*** Enhanced thermal insight, initiate payload re-configuration

- ***Interface description:***
  - The commercial vehicle will provide analog and discrete interfaces to each powered trunk payload. The vehicle can provide a constant current to drive and monitor payload resistance temperature detectors (RTDs). This will provide payload developers with temperatures at the payload site.

Sortie Payload Operations Support

2020 / CRS2

- The commercial visiting vehicles will be able to support science payload operations post-mating with ISS. Payloads can remain on the visiting vehicle and not cross the hatch to the ISS or they can be moved from the ISS onto the commercial vehicle for operations.

- ***Purpose:*** Expand NASA capacity for hosting research payloads

- ***Interface description:***
  - Once the commercial vehicle mates with the ISS, the ISS Joint Station LAN (JSL) and payload LAN will be extended into the vehicle.
  - Payloads will access ISS telemetry and command services while physically located on a visiting vehicle.

④ Technical and Programmatic Challenges Faced in Establishing These Services

Top Two Challenges

1. **Evolutionary nature of POIC interfaces with the commercial vehicle control centers:**

   - Many negotiations have to take place between the POIC and each commercial vehicle control center bi-laterally and NASA requirements for payload data services have expanded over time.

   - Determining the most efficient approaches for POIC network connectivity and ground segment design for all commercial vehicle interfaces is challenging since the interfaces are not being negotiated and set-up on the same timelines.

   - This has led to interface redesign that could have been avoided if the requirements for future services had been understood.

Top Two Challenges - 2

2. Getting ISS program consensus on the goals for these payload data services and how to balance competing objectives:

- **Objective 1:** Foster commercialization of low earth orbit (LEO)
  - Leaving implementation approaches for payload telemetry and command services open for vendor interpretation based on their commercial objectives and what is economically feasible.
- **Objective 2:** Support ISS payloads as they are currently designed with a common set of telemetry and commanding services
  - Requiring all commercial partners to implement telemetry and command interfaces for payloads the same way in a manner that is consistent with the interfaces available on the ISS today.
- **Objective 3:** Limit POIC ground system development costs
  - Requiring all commercial vehicle control centers to interface with the POIC the same way.

Resolution

- Going forward, the payload data services implemented on the commercial vehicles will have to support ISS payloads as they are currently designed.
  - Vendor-unique implementations would drive payload design changes and complicate the NASA manifesting process.
- Case-by-case decision on whether to enforce a POIC interface standard or accept a vendor-unique implementation.
- **Conclusion:** The POIC will strive to implement new interfaces with commercial partners in a manner that meets payload mission needs and priorities and that is cost effective for all parties.